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# ZEECO BURNER DIVISION

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Low NOx Duct Burners  
DB Series



## INTRODUCTION:

This document describes Zeeco's approach to designing the ZEECO® DB Series Low NO<sub>x</sub> burner to exceed environmental standards. To begin, this document defines each of the emissions normally associated with a duct burner (DB), and then provides insight to Zeeco's zone-analysis approach to designing custom, low-emissions DB applications.

### Duct Burner

A duct burner raises the temperature of air flowing through a large circular or rectangular duct. These burner systems consist of long runners that utilize the oxygen in the flow adjacent to the runners for combustion, rather than all air passing through a burner throat. Because of the long runner lengths in some applications, flow distribution in the duct is a critical parameter. Often times, these burners fire into turbine exhaust gas (TEG). Zeeco's engineers ensure each custom-designed DB application has sufficient oxygen and flow along the runner to achieve low emissions and short flame lengths.

### Typical Duct Burner Emission Issues

In a duct or vessel, uneven flow distribution results in uneven oxygen distribution, leading to higher emissions. Also, low-oxygen areas delay the combustion process, increasing flame length and potentially causing flame impingement on the tubes.

### DB Series Low NO<sub>x</sub> Burner Advantages

The ZEECO DB series:

- *Reduces the effect of uneven TEG / airflow*
- *Produces less NO<sub>x</sub> emissions*
- *Produces less CO emissions*
- *Produces less UHC emissions*
- *Produces less particulate emissions*
- *Provides more even heat distribution*
- *Reduces flame length*

## SPECIFICATIONS

The DB series is compatible with all turbine configurations and heat recovery systems. These burners are available for gas only, oil only, or combination gas and oil firing. Gas burners consist of one or more linear runner-type assemblies. Burner runners may be mounted vertically or horizontally. Oil is fired transversely in a self-contained system. All fuel-firing assemblies are mounted inside an insulated ductwork section

## DESIGN FEATURES

### Flame Length

Zeeco's duct burners produce an evenly distributed flame pattern. The DB series may be designed for a wide range of fuels and heat release duties per linear foot of length. However, for most applications the flame lengths are 4-to-6 feet depending on the conditions.

### Gas Firing

Gas-fired assemblies are constructed with specially-designed gas tips and flame holders to provide uniform heat release across the duct and to minimize emissions of NO<sub>x</sub>, CO, and unburned hydrocarbons. All materials of construction are high-alloy stainless steel for long life and superior performance.

### Turndown

The DB series achieves standard turndown ratios greater than 10:1 for natural gas. Higher turndowns are achieved in certain applications.

### Ignition

Zeeco's duct burners may be ignited with the Zeeco AR/GS forced draft pilot, a flame front generator, or a Zeeco S.E.T. high-energy electric igniter. Systems may be designed with one pilot runner to light all runners or with individual pilots on each runner.

### Maintenance

Zeeco's duct burners are designed for minimal maintenance. Gas runners and oil guns may be removed from the ducting for cleaning or repair.

### Fuels

Zeeco's duct burners operate on a wide range of fuels: natural gas, unsaturated hydrocarbons, plant gas, hydrogen, low-Btu gases, propane, butane, pentane and LPG mixtures, and syngas.

### Construction

Zeeco's duct burners are built for durability, reliability, and low maintenance. Each burner is constructed of materials that resist warpage and fuel coking when exposed to direct flames and radiation.

## DUCT BURNER CONTROL SYSTEMS

Zeeco provides a duct burner management system that meets safety and operational requirements. All control systems interface with existing plant computer-control systems. These systems are relay or PLC-based and may be designed to meet IRI, NFPA-85, FM, CSA, ATEX, or other requirements.



## EMISSIONS DESCRIPTIONS

### Thermal NO<sub>x</sub>

For gaseous fuels with no fuel-bound nitrogen, thermal NO<sub>x</sub> is the primary mechanism of NO<sub>x</sub> production.

### Thermal NO<sub>x</sub> production during combustion

Combustion occurs when O<sub>2</sub> reacts and is combined with fuel (typically hydrocarbon). In the combustion air, comprised of 21% O<sub>2</sub> and 79% N<sub>2</sub>, most of the nitrogen stream remains as diatomic nitrogen (N<sub>2</sub>). However, in high-intensity flame regions, N<sub>2</sub> may reach high enough temperatures to break apart and form “free” nitrogen. The “free” nitrogen most likely reacts with other “free” nitrogen, if available, to form N<sub>2</sub>. If not available, the “free” nitrogen and oxygen atoms react to form NO<sub>x</sub>.

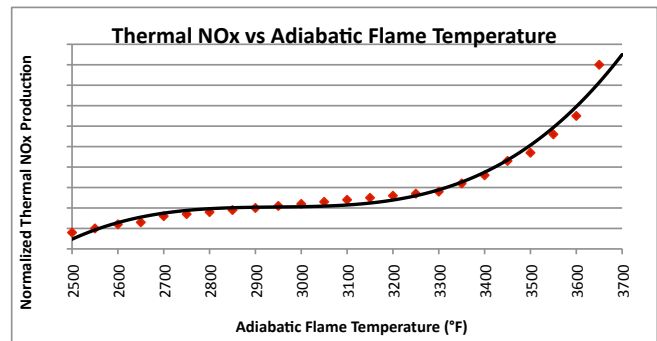
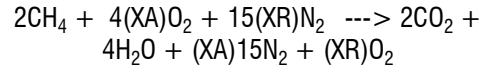
### Reducing NO<sub>x</sub> emissions

The method used to lower NO<sub>x</sub> emissions may differ depending on the application. However, thermal NO<sub>x</sub> reduction is generally achieved by delaying the rate of combustion.

The objective of delayed combustion is to reduce the rate at which fuel and oxygen mix together and burn. The faster these reactants mix together, the faster the rate of combustion and the higher the peak flame temperature. Slowing the combustion reaction reduces the flame temperature and, consequently, thermal NO<sub>x</sub> emissions.

The table below plots adiabatic flame temperature versus thermal NO<sub>x</sub> production. As shown, as the adiabatic flame temperature increases, NO<sub>x</sub> emissions increases.

### Methane & Air with Excess Air



### Carbon Monoxide (CO)

Carbon monoxide is the result of incomplete combustion. Almost every combustion process produces trace amounts of CO. Because CO is a toxic gas, it is strictly regulated.

### Carbon Dioxide (CO<sub>2</sub>)

Carbon dioxide is a colorless, odorless gas that is produced by natural sources and as a product of combustion. Increasing CO<sub>2</sub> concentrations in the atmosphere are believed to contribute to the greenhouse warming effect.

### Particulate Matter (PM<sub>10</sub>)

Particulate matter as defined here is a product of incomplete combustion. Particulate matter is most often produced when firing heavy fuel oils or when liquids are present in a fuel gas stream.

The US Environmental Protection Agency defines particulate matter under the federal code EPA 40 CFR Part 51.100 Definitions.

## Unburned Hydrocarbons and Volatile Organic Compounds

Unburned hydrocarbons (UHCs) and volatile organic compounds (VOCs) include a variety of low-molecular weight hydrocarbons produced as a result of incomplete combustion. Their release contributes to smog and ozone depletion.



### Reducing CO, PM<sub>10</sub>, UHC, and VOC Emissions

To minimize CO, PM<sub>10</sub>, UHC, and VOC production, most combustion processes incorporate more air than is required for stoichiometric combustion and a combustion temperature that is above a specific fuel's minimum combustion temperature. In general, higher temperatures result in an increasingly-reduced CO, PM<sub>10</sub>, UHC, and VOC production (if burned with sufficient combustion air).

### Sulfur Oxides (SO<sub>x</sub>)

During the combustion process, fuel sources containing sulfur compounds are burned, producing sulfur oxides. Sulfur oxides are a family of gases that may react with NO<sub>x</sub> and other chemicals in the air to form acid rain. Because SO<sub>x</sub> formation depends on the amount of sulfur in the fuel and the equilibrium conditions inside the furnace, SO<sub>x</sub> formation is not a function of burner design. As a result, SO<sub>x</sub> levels are not guaranteed by the burner manufacturer.

## CFD FLOW ANALYSIS AND ZONE ANALYSIS

For duct burner applications, the CFD (computational fluid dynamics) program may be used with zone analysis to:

- *Improve temperature distribution after the duct burner runners*
- *Minimize flame length*

Zeeco uses a more in-depth approach to CFD modeling, referred to as zone analysis.

### Zone Analysis Advantages

The benefits of the zone-analysis approach are:

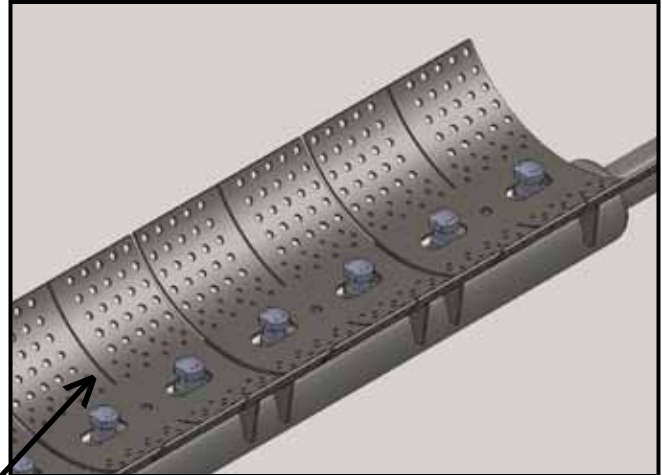
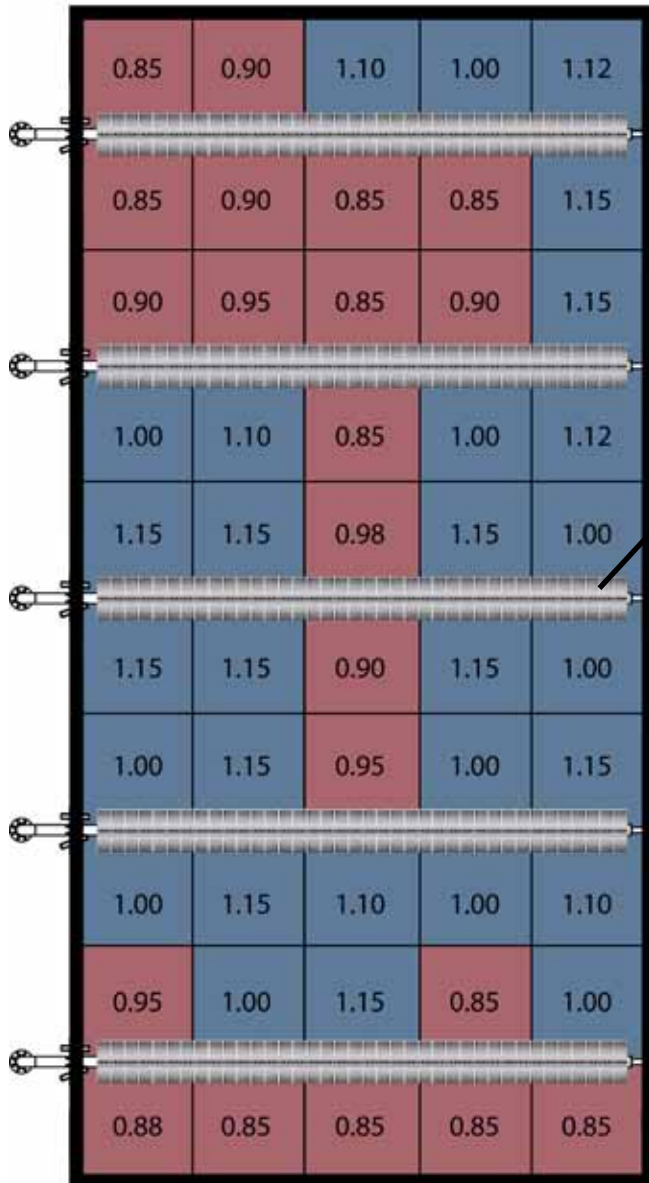
- *Lower thermal NO<sub>x</sub> production*
- *Lower CO production*
- *Lower UHC production*
- *Lower VOC production*
- *Lower particulate production*
- *Better exit temperature profile*
- *Shorter flame lengths*

### Zone Analysis Approach to Controlling Flame Length and Emissions

Zone analysis uses a grid layout to divide a duct into different sections. For each section, CFD analysis first determines the inlet conditions to the duct burner. Then, changes in flame length and emissions caused by the variance in flow are calculated for each section.

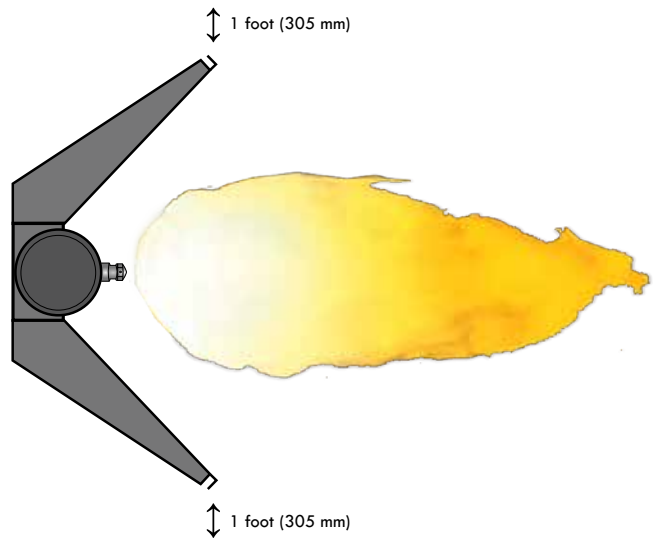
Since NO<sub>x</sub> production may increase with an increase in temperature and CO, particulate, VOC, and UHC may increase with a decrease in temperature. Emissions must exit each section at a temperature that is within a range that allows emissions to be controlled.

Based upon the results of flow analysis, the open area in the duct burner wing may be adjusted for the flow conditions of a particular section. By adjusting the amount of open area in the duct burner's wing, the emissions and flame heat pattern are better predicted and controlled.



3D duct burner model

TEG THAT DOES NOT TAKE PLACE IN COMBUSTION PROCESS



TEG THAT DOES NOT TAKE PLACE IN COMBUSTION PROCESS

Above is an example of flow distribution in a duct burner section. If the duct was provided with uniform distribution, all of the sections would be 1.00. Sections that are listed as 0.85 have 15% less flow than average and as 1.15 have 15% more than average. In this color-coded representation of flow distribution, the areas in red have less than average flow and the areas in blue have average flow or greater. In general, the red sections produce greater  $\text{NO}_x$  emissions and longer flames. The blue sections produce shorter flames and increased CO, UHC, VOC, and particulate emissions. Since Zeeco's wings are manufactured in-house, changes may be made to the amount of open area in problem sections and drillings to tailor the duct system for each application.

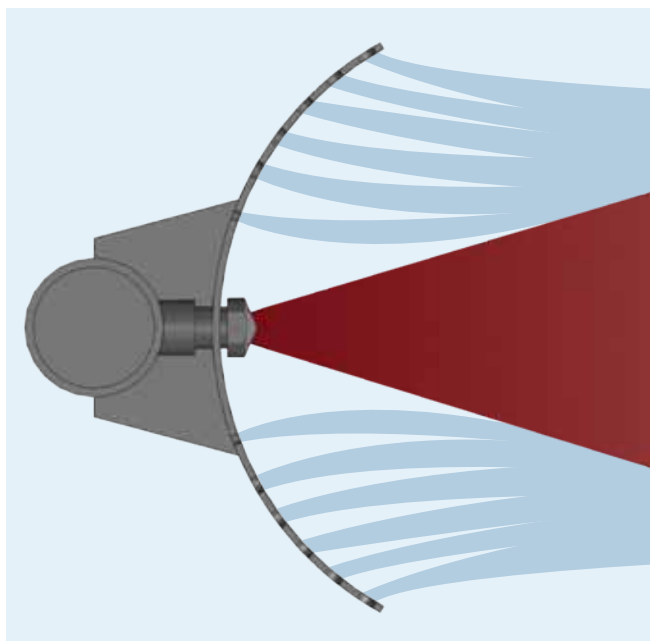
Since only the flow, approximately 1 foot (305 mm), on each side of the wing takes part in the combustion process, it is important to analyze each job using the zone analysis approach.

A) For applications with low-excess oxygen in the TEG stream, the width and the open area of the wing may be reduced to increase the peak flame temperature.

B) For applications with high-excess oxygen, the width and the open area of the wing may be reduced to decrease the peak flame temperature.

## DB SERIES LOW NO<sub>x</sub> DUCT BURNERS

Stringent environmental regulations have prompted the development of low-emission duct burners for use in turbine exhaust systems. To address the emissions environmental issue, Zeeco has redesigned its duct burner element to reduce NO<sub>x</sub>, CO, and unburned hydrocarbons. The DB series burner uses the free-jet mixing concept to combine the inert combustion products with the fuel gas before combustion occurs to form a new fuel composition that produces less thermal NO<sub>x</sub> emissions. The DB series design meets NO<sub>x</sub> emissions of 0.06 #/MM Btu (LHV) and 0.04# CO emissions for most typical applications.



*The custom-designed DB series achieves the correct TEG/combustion air flow into the primary combustion zone—resulting in low-CO, NO<sub>x</sub>, and other emissions. The gas (shown in red) ejects into the wing area of the duct burner and mixes with the TEG/combustion air flow via the free-jet mixing method. The amount of TEG/combustion air flow into the primary combustion zone is controlled per application by the amount of open area in the wing. For applications with low-oxygen content in the TEG steam, more TEG/air mixture is allowed into the duct burner wing. For applications with high-oxygen content in the TEG stream, less TEG/air mixture is allowed into the duct burner wing. Proper mixing ensures low NO<sub>x</sub>, CO, and other emissions.*

## SUMMARY

Zeeco equipment provides the best performance for the best value for your applications. To learn more about Zeeco products and services, contact the following locations:

### Headquarters:

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### Additional Offices:

**Zeeco – Houston, Texas**  
**Zeeco – Korea**  
**Zeeco – Europe**



**Zeeco's Test facility located at Broken Arrow, Oklahoma.**



**Zeeco's Duct Burner Test Rig. The simulated TEG is cooled by a running the TEG through a boiler to control the TEG inlet temperature to the duct runner at the correct temperature.**